Missouri Water Resources Research Center
Annual Technical Report
FY 2016

Introduction

Water Problems and Issues in Missouri

The water problems and issues in the State of Missouri can be separated into three general areas: 1) water quality, 2) water quantity, and 3) water policy. Each of Missouri's specific problems usually requires knowledge in these three areas. And as part of the food, water, and energy nexus, water contributes in a major way to the urban and rural communities in the state.

Water Quality

New media attention to the occurrence of pesticides in drinking water in the Midwest has raised a serious public concern over the quality of Missouri's drinking water and how it can be protected. Other concerns include the odor and taste issues when Missouri River water is used as source water for water supplies. With the large agricultural activity in the state, non-point source pollution is also of major interest. Because of several hazardous waste super-fund sites, hazardous waste is still of a concern to the public. The Centers research has been to evaluate the quality of current water sources and improve the methods to protect them. Areas of research for the past ten years have included (but are not limited to): erosion, non-point pollution reclamation of strip mine areas, hazardous waste disposal, nutrient management, water treatment and disinfection byproduct controls, wastewater treatment and reuse coupled with algal bioenergy production, acid precipitation, anthropogenic effects on aquatic ecosystems and wetlands.

Water Quantity

Missouri has a history of variable rainfalls. Because of the several drought years and major floods, water quantity has become a major topic of concern. The drought in 2012 was particularly notable with all counties in the State of Missouri being declared drought disaster areas with diminished agricultural and economic activities. Research is needed to better understand droughts and flood conditions. Many reservoirs have been constructed in Missouri to address water shortage issues; research is needed to understand how the agricultural activities affect water quality and how to best manage reservoirs and regional land use as a system. Also, a critical aspect is that research is needed on water treatment/reuse coupled with nutrient management.

Water Policy

Policies and program need to be formulated that will ensure continued availability of water for designate uses, as new demands are placed on Missouri's water. The social and economic costs may no longer be h acceptable levels if water becomes a major issue in cities and rural areas. Past droughts and possible low of the Missouri River have raised serious questions over states rights to water and priority uses. Best approaches for managing non-point source pollution need to be derived. Research areas in this program included drought planning, legal aspects, perception and values, economic analysis, recreation, land/water policy and legislation, and long-term effects of policy decisions.

Research Program Introduction

WATER PROBLEMS AND ISSUES OF MISSOURI

The water problems and issues in the State of Missouri can be separated into three general areas: 1) water quality, 2) water quantity, and 3) water policy. Each of Missouri's specific problems usually requires knowledge in these three areas.

Recent research activities include the following:

Stormwater Program

Federal regulations require MU, City of Columbia and Boone County to protect the quality of surface water from stormwater runoff. The Water Center has several projects to evaluate best management practices (B that will detain and filter the runoff. One project involves a diverse group from across campus to understand the best management practices for stormwater at the University of Missouri. The student team is laying groundwork to evaluate existing projects in preparation of data collection that will be used to inform future decisions. Allen Thompson, associate professor of biological engineering serves as principal investigator the project. In addition, Bob Reed research associate professor, Enos Inniss, assistant professor and Robe Broz, extension assistant professor with agricultural engineering, round out the mentoring team.

Renewable Energy

Ground source heat pump technology is being studied with application to the agriculture sector. The con temperature of the ground represents an incredible source of environmentally friendly, sustainable energy heat and cool the buildings. Dr. Shawn Xu, Research Associate Professor with the Water Center, is installing ground source systems on turkey farms in Central Missouri. The energy system is part of a Department of Energy grant ($5,000,000) that Dr. Xu received to introduce the technology into agriculture applications. Another project supported by the USDA under Drs. Robert Reed and Shawn Xu is focused on energy efficiency and control of ammonia in turkey farms.

Drinking Water

The Water Resources Research Center is working with several Missouri communities to manage disinfection byproducts (DBPs) that are produced during the disinfection of drinking water. DBPs are regulated compounds and can cause cancer. Led by Assistant Professor Enos Inniss and Research Associate Professor Robert Reed, the MWRRC research teams analyze the chemical makeup of water within each community treatment plant, water storage towers and distribution system throughout the year. The researchers then test how certain chemicals affect the water samples in order to identify options for complying with EPA guidelines. Funding has been available from EPA, Mo DNR, and various Missouri communities. Another project on the control of DBPs is to develop advanced ultra-filtration membranes to remove natural organic matters (NOMs), supported partially by the Water Center with Dr. Hu being the PI. NOMs are precursor DBP formation, and while nanofiltration and reverse osmosis are effective at removing NOMs, the cost i relatively high. Ultrafiltration could be implemented at a much lower cross-membrane pressure and thus be a cost-effective way for NOM removal and control of DBPs.

Wastewater Treatment

Water Center engineering researchers developed a portable wastewater treatment system for military bases that ultimately could produce water pure enough to drink. The portable treatment system treats the wastewater

with advanced membranes and disinfects chemically, producing reusable water that would save what often is a scarce resource as well as provide substantial savings. Zhiqiang Hu, associate professor, led the Water Center team. The Leonard Wood Institute provided the funding for this project ($832,699).

Homeland Security

The Water Center worked with the Department of Homeland Security on three related projects on drinking water (Best Practice protocols for Response and Recovery Operations in Contaminated Systems, understanding Economic Impacts of Disruptions in Water Service, and Studying Distribution System Hydraulics and Flow Dynamics to Improve Water Utility Operational Decision Making). Tom Clevenger and Bob Reed, College of Engineering and Tom Johnson, Truman Center, lead the Water Center team in working with the University of Kentucky, University of Louisville and Western Kentucky University.

A Novel Artificial Hormone Receptor for the Sensing of Total Endocrine Disruptor Chemicals (EDCs) Concentration in Natural Waters

Basic Information

Title:	A Novel Artificial Hormone Receptor for the Sensing of Total Endocrine Disruptor Chemicals (EDCs) Concentration in Natural Waters
Project Number:	2016MO150B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	MO-004
Research Category:	Water Quality
Focus Category:	Toxic Substances, Water Quality, Groundwater
Descriptors:	None
Principal Investigators:	Maria M Fidalgo, Chung-Ho Lin, Susan Nagel

Publications

There are no publications.

A Novel Artificial Hormone Receptor for the Sensing of Total Endocrine Disruptor Chemicals (EDCs) Concentration in Natural Waters

Year 1 results:

1. Colloidal Crystals and Porous Films: Fabrication and Characterization

We fabricated colloidal crystals by vertical deposition and self-assembly of silica particles obtained in the laboratory by the Stöber method. The particle sizes were characterized by Dynamic Light Scattering (DLS) and Scanning Electron Microscopy (SEM) with the ImageJ software (National Institutes of Health, NIH), resulting in diameters of 375± 7nm, 330±8nm, respectively. The relative standard deviation was less than 5%, therefore accepted for the intended application (Figure 1 (a)).

(a) (b)

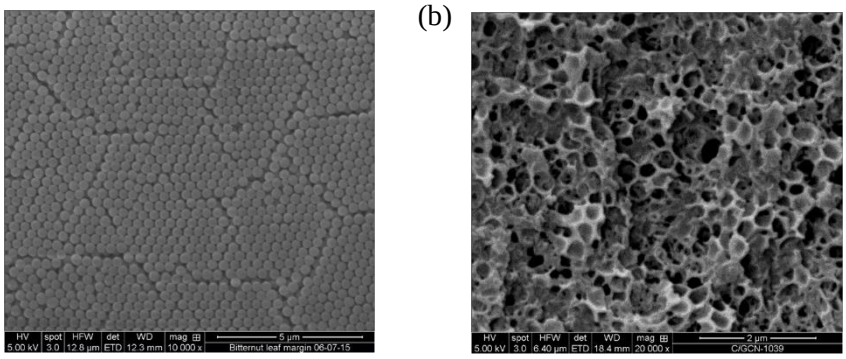

Figure 1. SEM images: (a) colloidal crystal; (b) porous polymeric film (molar ratio 1:0.1 of AA: EGDMA)

Obtaining a colloidal crystal of the needed dimensions (1.5 cm – 2 cm length) is a slow process when the deposition is conducted at room temperature, as we need to wait for the level of the ethanol suspension of silica particles drops by that same amount due to evaporation. However, fast deposition, as for example induced by reduced pressure or higher temperature, may lead to colloidal crystal growth limited by particle availability at the glass slide/suspension interphase, resulting in incomplete coverage and uneven layers. In this case, the film would lose its optical properties and detection by light reflection will not be feasible. Experiments at different temperatures / times showed that colloidal crystals with good order were achieved by self-assembly in the furnace at 50 ˚C for 24 hr. This method was used for the remainder of the experiments.

For the formulation of MIPs, mixtures were prepared from a functional monomer, EGDMA as crosslinker agent, AIBN as initiator, testosterone as the target molecule, and a solvent.

The monomers were polymerized under UV light at 365 nm for 3 hours at T = 25 °C. Then, the silica particles were removed by immersing the system for 12 hs in 5% hydrofluoric acid solution (Figure 1 (b)). after that the silica particles were removed by immersed the film inside (HF) 0.5 % for 12 hr and then wash by water and immersed in Acetic acid 0.1 M for 2 hr to remove the testosterone (Figure 1 (b)).

The properties of films from two different functional monomers were investigated: acrylic acid (AA) and methaacrylic acid (MAA). MAA was used as a comonomer in the mixture, at a 1:1 AA:MAA ratio. The addition of MA is expected to yield a more less hydrophobic polymer film which may result in slow response due to a decreased water absorption of the film and non-specific interaction with compounds; however, MA would improve mechanical strength and from more rigid, stable absorption cavities, which may have a beneficial effect in the recognition capacity. Poly-AA films are hydrogels and more hydrophilic than Poly-MAAA (comonomer); as such, they showed higher swelling ratios at neutral and basic environments. Contact angle measurements performed on nonporous thin films of 64 ± 2 ° for PAA and of 96 ± 2 ° for Poly-MAAA. The presence of MA made the films more manageable, as expected, due to the increased mechanical strength. The FTIR spectra were obtained for both polymers (Figure 2). The peaks at around 2955 cm^{-1} for both PAA and copolymer are associated with the methylene (- CH_2-). The bands due to the carbonyl group -C=O of PAA and copolymer overlap at 1737 cm^{-1}. The absence of the peaks at ~1600 cm^{-1} of unsaturated C=C stretch for both samples proves the absence of monomer impurities. The spectrum also displays bands at ~1450 cm^{-1} (scissors of CH_2), ~1230 cm^{-1} (OH bending of carboxyl group) and ~1170 cm^{-1} (C-O stretch).

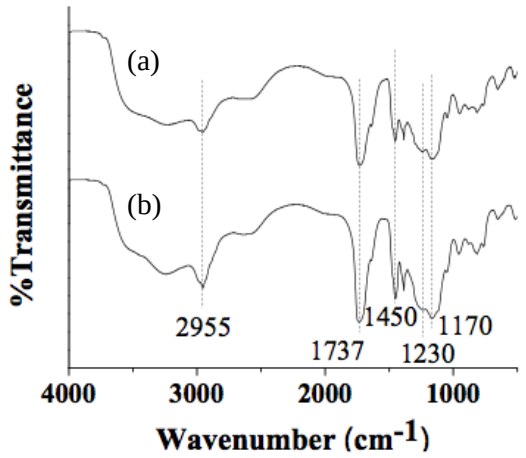

Figure 2. FTIR spectra of NIP-PMAAA (a) and NIP-PAA (b).

2. ***Film incubation – Effect of template removal method and functional monomer***

One of the common pitfalls in MIP fabrication is related to the incomplete removal of the template molecule before use, which may give rise to leaching of hormone into the sample being tested and leads to bias in the sensor. We investigated different washing strategies by comparing the recognition capacities (RC) in mg of hormone bound after incubation for 24 hours per gram of imprinted film. The weight of MIP's used in this experiment was 60 mg.

The different washing schemes were as follows: (A) washing with 1:1 (V:V) acetic acid / ethanol (20 ml) for 30 min once; (B) washing with 1M acetic acid solution in ethanol 6 times, each one 20-30 min.; (C) washing with 1M acetic acid solution in ethanol 6 times (30 minutes), followed by 2 hour washing by methanol once.

The results are presented in Figure 3, for the three procedures and different initial concentrations of testosterone. Approach A gave the best results regarding RC. The films appeared to showed signs of damage by prolonged exposure to acetic acid, which may be partially responsible for the poor performance of the films subjected to extensive cleaning. In order to avoid this damage, the films were thoroughly rinsed with water after the treatment.

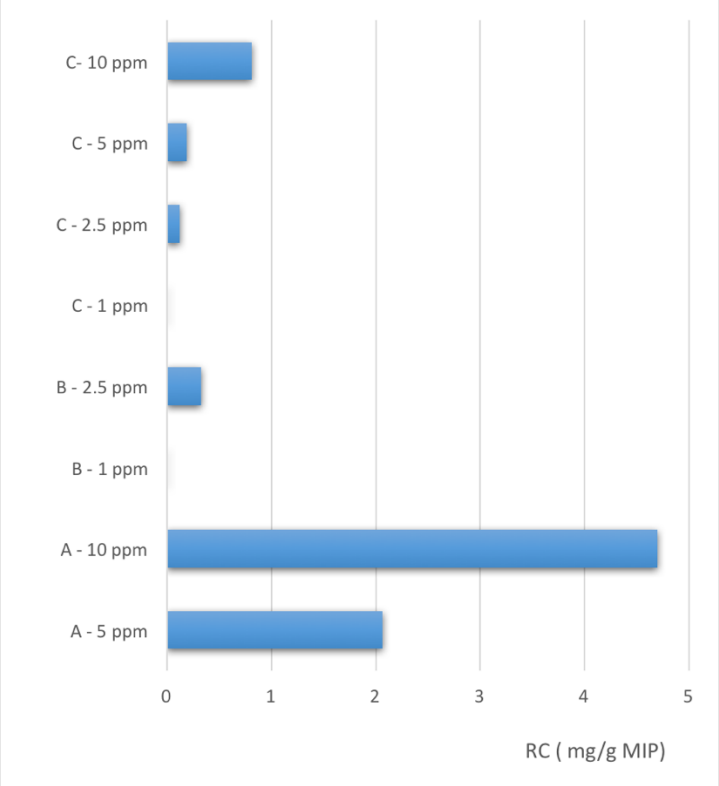

Figure 3. Recognition capacity of MIP films after target removal processes A, B, and C (see text for details)

The different monomers considered were used in the fabrication of MIPs and non-imprinted polymers (NIPs) with same morphology but lacking the specific binding pockets created by the target molecule. The films were subjected to the same incubation experiments. The RC value for the NIPs in an indication of the degree of non-specific binding and it is expected to be

much lower than the MIPs RC. However, the Poly-AA films gave RC_{MIP}:RC_{NIP} ratios much higher than the other two materials (data not shown for brevity), so all experiments were continued with AA as the functional monomer.

3. Testosterone Attachment Kinetics

The kinetics of the capture of testosterone by a PAA MIP and NIP was investigated, and results presented in Figure 4.

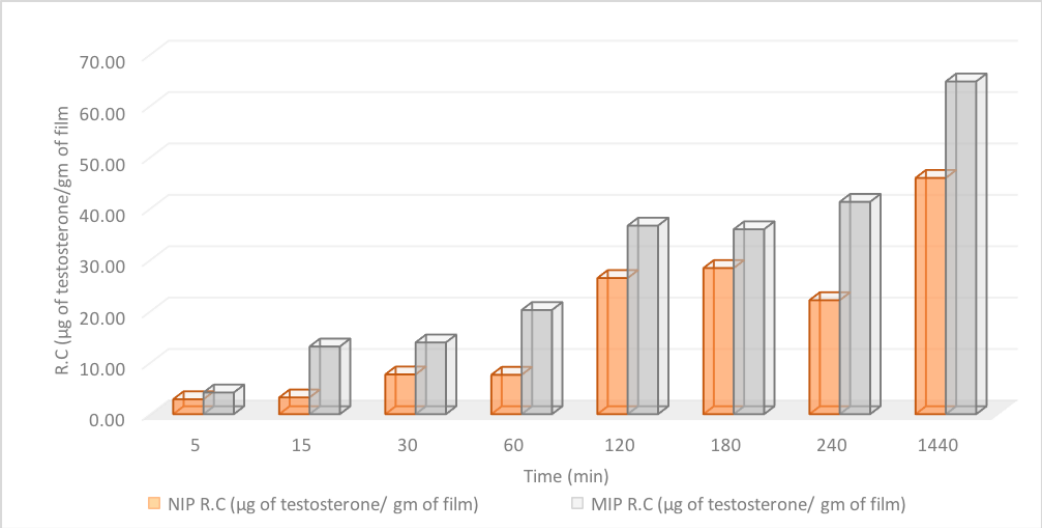

Figure 4. Observed RC for PAA MIPs and NIPs as a function of incubation time; Co= 5 mg/L testosterone.

Adsorption was consistently higher for the MIP, and also faster in the first minutes of the incubation. After 200 minutes, the increase in adsorption is proportional for both materials. Figure 3 shows the evolution of recognition capacity for both films. Although adsorption increases with time, the maximum RC_{MIP}:RC_{NIP} occurred at 15 minutes. At his time, the sensor exhibits the best specificity and it is also a reasonable time for practical purposes. We therefore propose that all sensor tests be performed at an incubation time of 15 minutes. We are currently performing further experiments to confirm this value.

4. Testosterone Concentration Sensing by Reflectance Measurements

We started work in order to determine our ability to quantify testosterone re binding to the film by measuring the spectra of the light reflected by the 3-D porous films, before and after incubation in the presence of the target molecule.

In this task, the binding of the target molecules was quantified through the change in diffraction properties of the ordered structure of the MIP. The diffraction peak λ_{max} for the porous hydrogel is determined by the Bragg equation:

$$\lambda_{max} = 1.633(d/m)(D/D_0)(n_a^2 - \sin\theta^2)^{0.5}$$

where d is the sphere diameter of the silica colloidal particle, m is the order of Bragg diffraction, (D/D_0) is the degree of swelling of the gel (D and D_0 denote the diameters of the gel in the equilibrium state at a certain condition and in the reference state, respectively), n_a is the average refractive index of the porous gel at a certain condition, and θ is the angle of incidence. Analyte adsorption into the binding sites results in a change in Bragg diffraction of the polymer.

UV-vis spectra of the films were recorded and their respective shifts in λ_{max}, before and after incubation, related to testosterone initial concentration in the sample. Reflectance of the photonic hydrogel films was measured over a wavelength range of 200–800 nm, using a double-beam UV–Vis–NIR spectrophotometer (Cary 60, Varian) with a Harrick Scientific's Specular Reflection Accessory (ERA-30G) for measurement reflectance at 30 degrees.

The spectra obtained before (clean) and after incubation in testosterone solutions of concentrations ranging from 5 ppm to 100 ppb are shown in Figure 5. Both the intensity of the reflectance and the wavelength of the peak changes with increasing concentration, and therefore is responsive to the amount or rebinding of the target molecule (Figure 5a). On the other hand, the peak of maximum reflectance remained constant under the same conditions for the NIPs films. The shift in the maximum wavelength is therefore associated with specific binding of the target molecule into the imprinted sites and it is not affected by the non-specific adsorption.

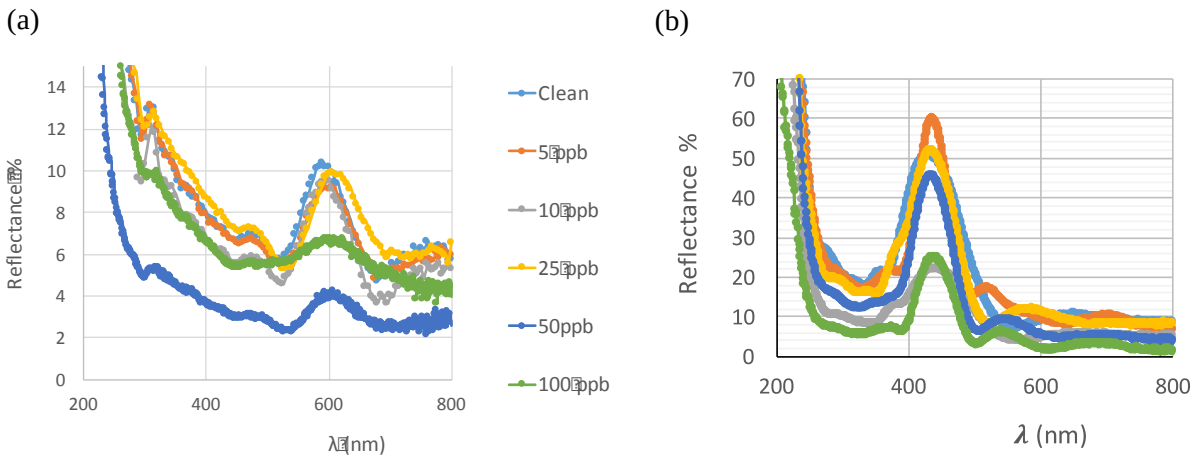

Figure 5. Reflectance spectra of PAA MIPs(a) and NIPs(b) after incubation in testosterone solution of variable concentration; incubation time= 30 minutes; initial concentration= 0 to 100 ppb testosterone.

The wavelength shift was calculated for each spectrum and compared to the one recorded before (clean) exposure to testosterone to calculate the shift induced at each concentration of target molecule. The response (shift) as a function of sample concentration is shown in Figure 6. The NIP films show negligible variation in maximum wavelength, but the MIP films' shift shows a linear correlation with initial concentration in the sample. The thickness of the sensor films used were very thin (micron range) and actual surface area per sensor was low enough so that the change in concentration due to binding on the polymer can be neglected; therefore, we can expect the measurement procedure to not affect the sample, i.e. initial and final concentration of testosterone in the liquid after the incubation period was assumed to be equal.

The linear relationship between the shift and sample concentration allows for the technique to be used for quantification of the testosterone level in solution.

We are currently working in follow up experiments to determine the detection limit and the quantification limit of the sensors in pure water conditions, as well as the influence of water matrix on the sensitivity of the technique.

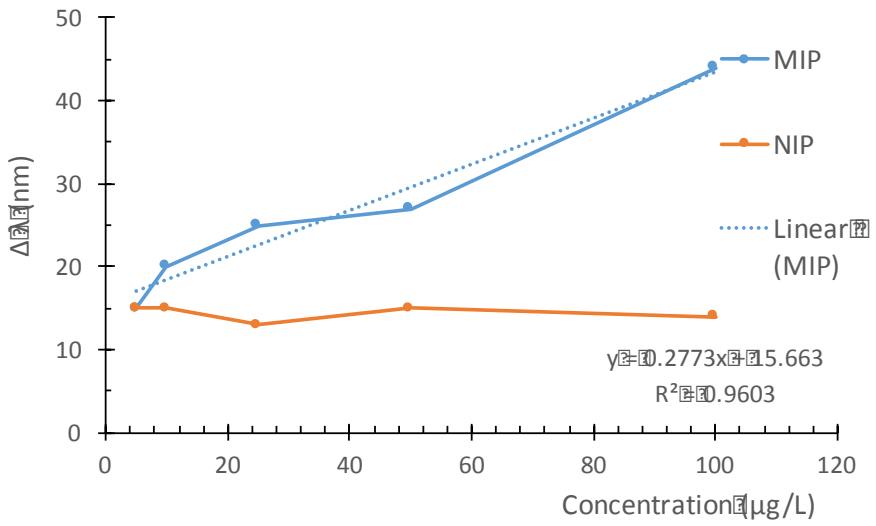

Figure 6. Maximum wavelength shift recorded after incubation at variable concentrations of testosterone, MIP and NIP films; linear fit for the MIP films response.

The cost effectiveness of the sensor is directly related to its shelf life and the possibility of reuse. Regarding the former, MIPs showed no evidence of degradation when store in the lab at regular ambient conditions even after more than 1 year of fabricated. The reuse was investigated, subjecting a film to several cycles of use and regeneration by solvent washing. The results of 12 consecutive uses of a single film are reported in Figure 7. Even after the 12th rinse, the sensor is able to return to its original state and produces a similar response (maximum wavelength) than in the first use. These results indicate a high reusability for the material is expected.

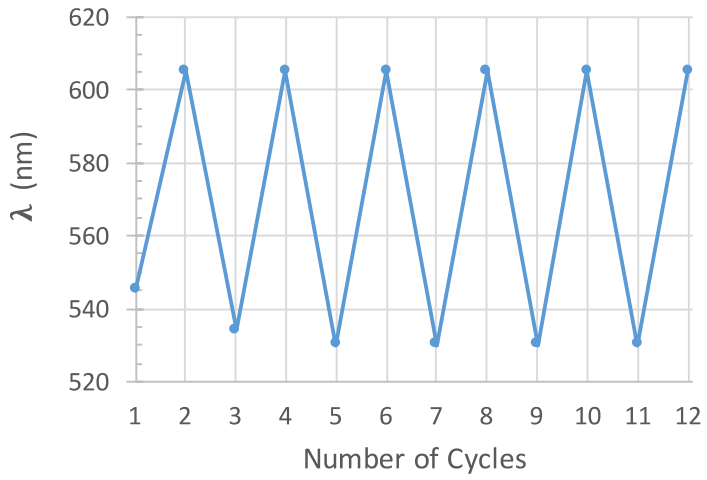

Figure 7. Sensor response after consecutive cycles of incubation and washing; sample testosterone concentration = 100 ppb; incubation time = 30 minutes; washing solvent: 9:1 ethanol:acetic acid.

Principal Findings and Significance:

We were able to successfully synthesize a molecular imprinted polymer using testosterone as the target molecule, through selection of the active monomer and the elution solvent.

In order to provide high surface area as required for fast re binding, the polymer was fabricated inside the void volume of a colloidal crystals. Silica particles of narrow size distributions were synthesized to grow the colloidal crystals and obtain a porous film supported on a plastic (PMMA) slide to be used as a sensor.

The MIPs showed significantly improved recognition capacity than the non-imprinted polymers with similar surface area, which indicates a predominance of specific over non-specific adsorption (binding in cavities rather than general surface adsorption).

We investigated the optical properties of the films for the assessment of re binding into the imprinted cavities. We found that the wavelength of the reflected light from the sensor is highly sensitive to re binding, and in particular the shift in wavelength displayed a linear relationship with sample concentration. Moreover, non-specific

adsorption, as that occurring in non-imprinted polymer films, did not cause measurable variation in wavelength of reflected light, increasing specificity. These results indicate the possibility of using the films to quantify testosterone concentration in unknown samples.

Finally, we demonstrated the reusability of the fabricated sensor, which showed excellent reproducibility after up to 12 stages of use and regeneration.

Satellite-Imagery Based Method for Water-Quality Monitoring and Sediment Budgeting along the Middle-Mississippi River and Its Tributaries

Basic Information

Title:	Satellite-Imagery Based Method for Water-Quality Monitoring and Sediment Budgeting along the Middle-Mississippi River and Its Tributaries
Project Number:	2016MO151B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	1
Research Category:	Water Quality
Focus Category:	Sediments, Water Quality, Surface Water
Descriptors:	None
Principal Investigators:	Amanda Lee Cox, Abuduwasiti Wulamu

Publications

1. L.S.F, Pereira, Andes, L.C., Cox, A.L., and Ghulam, A. (In Review). Measuring Suspended-Sediment Concentration and Turbidity in the Middle Mississippi and Lower Missouri Rivers using Landsat Data. submitted to the Journal of the American Water Resources Association on March 19, 2017.
2. Pereira, L.S.F. (2016). Landsat Imagery Based Method for Characterization of Suspended-sediment Concentration along the Middle-Mississippi River and Lower Missouri River. M.S. Thesis, Saint Louis University, Department of Civil Engineering, St. Louis, MO.
3. Pereira, L.S.F., Andes, L.C., Cox, A.L., and Ghulam, A. (2016). Remote Sensing of Suspended Sediment Concentration along the Middle-Mississippi River Geological Society of America GSA North-Central Section 50th Annual Meeting, presented April 18-19, Champaign, MO.
4. Pereira, L.S.F., Andes, L.C., Cox, A.L., and Ghulam, A. (2016). Remote Sensing of Suspended Sediment Concentration along the Middle-Mississippi River 22nd Annual Graduate Student Association Research Symposium, presented April 22, St. Louis, MO.

Satellite-Imagery Based Method for Water-Quality Monitoring and Sediment Budgeting along the Middle-Mississippi River and Its Tributaries

Abstract

Suspended sediment concentration (SSC) and suspended sediment load (SSL) along the Middle-Mississippi River (MMR) and its tributaries are of significant interest to researchers, engineers, scientists, and water resources managers as sediment erosion, deposition, and transport are fundamental to geomorphic and ecological conditions of the river. Sediment deficits can cause channel degradation that threatens adjacent infrastructure, reduces available terrestrial and aquatic habitat, and changes water quality to such a degree that species become threatened. Conversely, sediment surplus can lead to channel aggradation that is hazardous to navigation, reduces performance of water-intake structures, and increases the amount of nutrients and contaminants introduced to the system that contribute to basin-wide issues such as gulf hypoxia.

Currently, in Missouri and Illinois 14 gauge stations on five rivers have monitored water-quality parameters. These gauges have been used to quantify a general trend of decreasing sediment supply from the Missouri River, which reinforces a growing need to understand trends in local sediment sources and sinks that contribute to the regional and basin-wide sediment budget. Spatial resolution of U.S. Geological Survey (USGS) monitoring stations and the fragmented nature of associated datasets make quantification of a local sediment budget difficult as there are a large number of unmonitored rivers and streams in the area. Recent advancements of remote sensing technologies have led to capacities to characterize surficial SSC in fluvial environments.

The objective of the proposal is to develop a satellite-imagery based algorithm to monitor surficial SSC along the MMR between the Mississippi River-Missouri River and Mississippi River-Ohio River confluences. The efforts proposed in this work will generate a time history of surficial SSC and SSL to (1) supplement fragmented datasets at existing USGS gauge locations and (2) create new data for unmonitored tributaries along the MMR. Following development of the time histories of surficial SSC and SSL, these data will be used to estimate a local sediment budget of the study area. The resulting SSC data will be made available to the Missouri Water Resources Research Center for quality assurance and quality control with the intent that the proposed work may be integrated into existing USGS databases for public use.

This proposal is for the second year of funding for an existing project. This proposal provides the results to date for the project and details the tasks to be completed during the second year. Over the past year, previous regression models were reviewed to provide the foundation for development of the regional model. Publically-available Landsat imagery with 30-meter spatial resolution was obtained from multiple Landsat sensors covering a 33-year period (1982 to present day). A database of available images was developed using pixels co-registered with the USGS gauge locations of interest. The images were filtered for cloud coverage, vessel traffic, and radiometrically and geometrically corrected. USGS gauge data of SSC and turbidity from the USGS Sediment

Data Portal and USGS National Water Information System databases were retrieved and filtered for data anomalies. The USGS gauge stations and corresponding reflectance were divided into a development group and a test group. A best-fit linear regression model was created using the development group for both suspended sediment concentration and turbidity. The test group was used to validate the model through comparison of SSC values computed using the remote-sensing model and in-situ SSC measurements.

The scope of work proposed for this coming year includes using the model to estimate SSC at approximately 17 tributaries along the Mississippi River (13 are completely unmonitored and 2 only monitor stage/discharge). A time series of surficial SSC will be developed for each tributary and SSL into the Mississippi River will be quantified for the 33-year period of record that Landsat images are available. Associated flow discharges for each of the tributaries will be estimated and used with the SSC to compute the SSL. Trends in the seasonal, annual, and decal sediment budget of the MMR will be evaluated using the computed SSL data.

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Satellite-Imagery Based Method for Water-Quality Monitoring and Sediment Budgeting along the Middle-Mississippi River and its Tributaries

Annual Progress Report

USGS Grant G16AP00066
Missouri Water Resources Research Center

May 2017

Principal Investigator:
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Submitted to:
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Introduction

This annual report describes the activities between March 1, 2016 and February 28, 2017 for the project funded through the USGS Grant G16AP00066 including details of products generated, dissemination activities, and student involvement. The project objective is to develop a satellite-imagery based algorithm to monitor suspended sediment (SSC) along the Middle-Mississippi River (MMR) between the Missouri River and Ohio River confluences with the Mississippi River. This objective is being achieved through the following tasks: (1) a critical review of previous work, (2) identification of available data to be used in the analysis, (3) methodology development, (4) validation of method transferability, (5) estimation of SSC at unmonitored tributaries along the MMR, (6) development of a local sediment budget, and (7) data preparation for integration into a publically-available data portal. Task 1, Task 2, Task 3, and Task 4 have been completed. Task 5 and Task 6 are underway with scheduled completion dates of August 31 and November 30, respectively.

Products and Dissemination Activities

Journal Article in Review (included as an attachment)

Pereira, L.S.F., Andes, L.C., Cox, A.L., and Ghulam, A. (In Review). "Measuring Suspended-Sediment Concentration and Turbidity in the Middle Mississippi and Lower Missouri Rivers using Landsat Data." submitted to the Journal of the American Water Resources Association on March 19, 2017.

Masters of Science Thesis

Pereira, L.S.F. (2016). Landsat Imagery Based Method for Characterization of Suspended-sediment Concentration along the Middle-Mississippi River and Lower Missouri River. M.S. Thesis, Saint Louis University, Department of Civil Engineering, St. Louis, MO.

Abstracts Presented at Conferences and Symposiums

Pereira, L.S.F., Andes, L.C., Cox, A.L., and Ghulam, A. (2016). "Remote Sensing of Suspended Sediment Concentration along the Middle-Mississippi River" Geological Society of America GSA North-Central Section 50th Annual Meeting, presented April 18-19, Champaign, MO.

Pereira, L.S.F., Andes, L.C., Cox, A.L., and Ghulam, A. (2016). "Remote Sensing of Suspended Sediment Concentration along the Middle-Mississippi River" 22nd Annual Graduate Student Association Research Symposium, presented April 22, St. Louis, MO.

Other Presentations

Cox, A.L. (2016). "Use of Remote Sensing to Monitor Suspended Sediment Concentrations in the Middle Mississippi River." presented as a webinar for the St. Louis Chapter of the Environmental and Water Resources Institute (EWRI) of the American Society of Civil Engineers (ASCE), December 15, St. Louis, MO.

Cox, A.L. (2016). "Using Remote Sensing as a Surrogate Method for Suspended Sediment Concentration Measurements along the Middle-Mississippi River." Invited Speaker for the Joint Seminar Series of the University of Mississippi National Center for Computational Hydroscience and Engineering and the U.S. Department of Agriculture – Agricultural Research Service National Sedimentation Laboratory, October 25, Oxford, MS.

Student Involvement

Under the direction of the PI and Co-PI, four students contributed to the project - a masters student, two Ph.D. students, and an undergraduate research assistant. The masters student, who graduated in December 2016, completed the majority of the work with technical assistance from a Ph.D. student. The research activities have continued with the undergraduate research assistant with technical assistance provided by a second Ph.D. student. The undergraduate research assistant will be a masters student at Saint Louis University in the fall and she will complete the remaining research tasks under the direction of the PI and Co-PI.

Information Transfer Program Introduction

The Missouri Water Resources Research Center's objectives are: 1) to establish active research programs to aid in understanding and solving Missouri's and the Nation's water problems, 2) to provide education opportunities in research for students with an interest in water resources and related fields, and 3) to be actively dedicated to the dissemination of information through all aspects of the media.

The goal of the Information Transfer Program is to meet objective 3, dissemination of information through all aspects of the media.

Technology Transfer

Basic Information

Title:	Technology Transfer
Project Number:	2016MO149B
Start Date:	3/1/2016
End Date:	2/28/2017
Funding Source:	104B
Congressional District:	4
Research Category:	Not Applicable
Focus Category:	None, None, None
Descriptors:	None
Principal Investigators:	Baolin Deng

Publications

There are no publications.

The Center maintained an active information transfer program that included: 1) coordination of the University of Missouri seminar program, 2) publication of Water Center newsletter, 3) interaction with state and federal water agencies, 4) Director served on various national and local water related boards, organizations and committees, 5) continued cooperation with district USGS office (representative on advisory committee), 6) maintenance and expansion of comprehensive web site, 7) making available of Center's publications, 8) responding to public requests and questions, 9) meeting with advisory committee to improve information transfer activities.

Coordination of Seminar Program

The Water Resources Research Center hosted a joint University of Missouri-Columbia seminar series with Civil & Environmental Engineering & Chemical Engineering throughout the year. In addition, other special seminars included speakers from out of state and internationally to speak on a variety of topics:

1) Dr. Haizhou Liu, University of California, Riverside, “Redox Chemical Processes of Hexavalent Chromium in Drinking Water.” December 9, 2016

2) Dr. Timothy Strathmann, Colorado School of Mines, “Resource Recovery from Algal Biomass and biomass-Derived Acids through Hydrothermal Conversion Technologies.” April 29, 2016

3) Dr. Vlad Tarabara, Michigan State University, “Human Adenovirus Removal in Membrane bioreactors: Mechanisms and Implications.” April 22, 2016

4) Dr. Jeffery Steevens, United States Geological Survey, Columbia Environmental Research Center, “His research activities focus on assessing the bioavailability and toxicity of environmental contaminants in water and sediments.” February 10, 2017.

5) Dr. Edward, Bouwer, John Hopkins University, “Water Supply Challenges in the U.S.” November 4, 2016.

Publication of the Water Center Newsletter

The Water Center newsletter is a yearly publication. The purpose of the Centers newsletter is to inform the scientific community as well as the public, of the activities

of the Center, i.e., new research projects funded, and upcoming conferences. The Centers primary focus is on its own information transfer activities and the general scope of the projects that were funded. Highlights of the 2014 Newsletter can be seen on the Missouri Water Resources Research Center website at http://engineering.missouri.edu/water/.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	2	0	0	0	2
Masters	1	0	0	0	1
Ph.D.	4	0	0	0	4
Post-Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements

For the Project Removal of NOMs by Advanced Thin Film Composite Membranes for the Control for Disinfection Byproducts, Project Number 2015MO147B, with the help of the USGS support, we have developed nanocomposite membranes capable of water purification more efficiently and with better anti-fouling ability.

Publications from Prior Years

1. 2009MO99B ("Visible Light-activated Titanium Dioxide-based Photocatalysts: Synthesis and Potential Environmental Applications ") - Articles in Refereed Scientific Journals - Abell, J.M., D. Özkundakci, D. P. Hamilton, and J. R. Jones. 2012. Latitudinal variation in nutrient stoichiometry and chlorophyll-nutrient relationships in lakes: A global study. Fundamental and Applied Limnology 181:1-14.
2. 2009MO99B ("Visible Light-activated Titanium Dioxide-based Photocatalysts: Synthesis and Potential Environmental Applications ") - Articles in Refereed Scientific Journals - Michaletz, P.H., D. V. Obrecht, J. R. Jones. 2012. Influence of environmental variables and species interactions on sport fish communities in small Missouri impoundments. North Amer. J. of Fisheries Manage. 32:6, 1146-1159.
3. 2009MO99B ("Visible Light-activated Titanium Dioxide-based Photocatalysts: Synthesis and Potential Environmental Applications ") - Articles in Refereed Scientific Journals - Pittman, B., J. R. Jones, J. Millspaugh, R. J. Kremer and J. A. Downing. 2013. Sediment organic carbon distribution in 4 small northern Missouri impoundments: implications for sampling and carbon sequestration. Inland Waters 3:39-46.
4. 2009MO99B ("Visible Light-activated Titanium Dioxide-based Photocatalysts: Synthesis and Potential Environmental Applications ") - Articles in Refereed Scientific Journals - Jones, John R., Daniel V. Obrecht, Jennifer L. Graham, Michelle B. Balmer, Christopher T. Filstrup, and John A. Downing. Seasonal patterns in carbon dioxide in 15 mid-continent (USA) reservoirs. Inland Waters (2016) 6, pp.265-272.
5. 2015MO147B ("Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts") - Articles in Refereed Scientific Journals - Kadhom, Mohammed, Jun Yin, Baolin Deng, A Thin Film Nanocomposite Membrane with MCM-41 Silica Nanoparticles for Brackish Water Purification, Membranes 2016, 6, 50.
6. 2015MO147B ("Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts") - Articles in Refereed Scientific Journals - Yin, Jun, Guocheng Zhu, Baolin Deng, Graphene oxide (GO) enhanced polyamide (PA) thin-film nanocomposite (TFN) membrane for water purification, Desalination 379 (2016) 93 101.
7. 2014MO145B ("Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts") - Articles in Refereed Scientific Journals - Hu, Weiming, Jun Yin, Baolin Deng, Zhiqiang Hu, Application of nano TiO2 modified hollow fiber membranes in algal membrane bioreactors for high-density algae cultivation and wastewater polishing, Bioresource Technology 193 (2015) 135 141.
8. 2014MO145B ("Removal of NOMs by Advanced Thin Film Composite Membranes for the Control of Disinfection Byproducts") - Articles in Refereed Scientific Journals - Yin, Jun, Baolin Deng, Polymer-matrix nanocomposite membranes for water treatment, JMembrSci(2015), http: //dx.doi.org/10.1016/j.memsci.2014.11.019i.